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Improving tree establishment with forage crops

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ABSTRACT

Tree establishment in Iowa can be difficult without adequate weed control. Although herbicides are effective at controlling weeds, they may not be desirable in some situations. An alternative to herbicides is using forage crops as cover crops to control weeds. The objectives of this research were: (i) evaluate the influence of various weed control methods on the growth and survival of five tree species and (ii) determine the cost effectiveness of planting trees with different weed control treatments. Seven weed control treatments were used: (i) oats (*Avena sativa* L.) and red clover (*Trifolium pratense* L.), (ii) oats, red clover, and red fescue (*Festuca rubra* L.), (iii) oats, red clover, and orchardgrass (*Dactylis glomerata* L.), (iv) oats and hairy vetch (*Vicia villosa* Roth.), (v) herbicide, (vi) mowing, and (vii) control (no treatment). Five species of trees were planted in two groups; the first group (fast-growing trees) contained two poplar (*Populus* spp.) clones [Crandon (*P. alba* L. x *P. grandidentata* Michx.) and Eugenii (*P. deltoids* Bartr. x *P. nigra* L.)] and silver maple (*Acer saccharinum* L.). The second group (slow-growing trees) consisted of high-value hardwoods, red oak (*Quercus rubra* L.) and black walnut (*Juglans nigra* L.), both planted from seedlings and seeds. Height and survival were measured yearly for all tree species, and forage crop coverage was estimated during the third and fourth growing seasons. The treatments did not appear to influence seedling survival ($P \geq 0.28$). Trees grown in herbicide plots were significantly taller (3.2 m) than those in the other treatments (2.5 m) ($P < 0.02$). Forage treatments outperformed mowing and control treatments in three out of four experimental groups ($P \leq 0.05$). In addition, after four years black walnut seedlings from seed were taller (1.4 m) than planted seedlings (1.2 m) ($P \leq 0.02$), indicating direct seeding is a viable alternative to planting seedlings. An economic analysis was conducted by estimating the costs and returns with different weed control treatments for black walnut and Crandon. For black walnut, net present value increased by $438/ac when forage crops were used for weed control and harvested versus using herbicides for weed control. Under the same scenario, Crandon net present value decreased $861/ac.

CHAPTER 1. GENERAL INTRODUCTION

Introduction

In the late 1800's, an estimated six and a half million acres of forest covered Iowa (Wider 1968). Currently, there is an estimated two million acres of forest in the state (USDA 1997). Many of the nearly four million acres that were forested have been converted to farmland that is used for crop production or pasture. This land conversion has had a significant impact on the status of the environment in Iowa. A survey conducted by the USDA in 1997 found that over eight million acres of Iowa cropland is considered highly erodible. A significant portion of that land was once forested.

Iowa has lost, on average, more than 50% of its topsoil from erosion (Pimentel et al. 1995). Current estimates indicate that Iowa cropland loses about six tons of topsoil per acre each year (USDA 1997). When perennial plant communities are replaced with annual crops, nutrients are more likely to leach through the soil and microbial activity in the soil is reduced in response to soil compaction and lower levels of soil C (Schultz et al. 2000). It is estimated that 43 and 40% of the annual inputs of N and P, respectively, to surface waters come from cropland (Welsch 1991). Establishing trees on highly erodible acres would take them out of agricultural production and decrease erosion and runoff of fertilizers and pesticides.

In addition to converting agricultural fields back into forests, another method that could potentially incorporate more trees into the rural landscape of Iowa is agroforestry. Agroforestry, as defined by Gold et al. (2000), is intensive land-use management that optimizes the benefits (physical, biological, ecological, economic, social) from biophysical interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock.

Some agroforestry methods that would be feasible in Iowa include shelterbelts, riparian bufferstrips and alleycropping. Shelterbelts are rows of trees and/or shrubs that border crop fields protecting them from wind, which reduces wind erosion and, in some cases, increases crop yield of the field it protects. Riparian bufferstrips incorporate trees, shrubs, and grasses that protect streams from nutrient and sediment runoff from cropfields. They filter runoff of agricultural fields, reducing the amount of sediment and nutrients placed into the stream. In addition, riparian bufferstrips stabilize streambanks and improve habitat for aquatic and terrestrial creatures. Alleycropping is a system in which trees are planted in widely spaced single or multi-rows with agricultural or horticultural crops grown between the rows. This provides early income from seasonal crops, while the trees are young. Nut bearing crops, like walnut and pecan, are popular in alleycropping systems for the income the nuts bring while the trees mature. Finally, high-value timber or veneer can be harvested from the site, thus completing the rotation.

With proper care, trees can provide a source of income from products, such as fuelwood, sawlogs, veneer, fruits and nuts. In addition, trees provide habitat for wildlife and are aesthetically pleasing. However, even with support from Trees Forever, the Conservation Reserve Program, and the Resource Enhancement and Protection (REAP) program, tree establishment can be difficult and expensive. Better methods of establishing trees are needed to increase the number of acres of forest in Iowa and other midwestern states.

Two methods of establishing trees that might be less expensive and easier than traditional methods have been evaluated. The first method uses forage crops to control weeds in tree plantings. This method can yield an income from harvesting the forage crop in the initial years of tree establishment, which can partially offset planting costs. The other method being evaluated is establishment of trees with direct seeding. In the past five years direct seeding has become increasingly popular, over 175 plantings covering 2500 acres have been planted using the direct seeding method in Iowa. In addition, this technique can be less expensive than planting seedlings, making it an ideal alternative method for tree planting.

In 1998, a research project called the Forage and Tree Experiment (FATE) was established in Iowa to determine the effectiveness of forage crops as weed control cover crops. Four forage treatments were compared against more traditional methods of weed control during tree establishment: herbicides, mowing, and nothing. Growth and survival were measured on three tree species and two poplar clones. In the FATE project, two of the tree species were established via seedlings and seeds. This allowed for a direct comparison of growth rates using different planting methods.

Thesis Organization

The first chapter of this thesis is devoted to a review of relevant scientific literature. The topics covered are agroforestry, weed control during tree establishment, forage crops and trees, and direct seeding. The second chapter consists of an article to be submitted to the Northern Journal of Applied Forestry. The thesis is summarized in the last chapter with general conclusions. The appendix (Tables A1-A8) contains data collected from the experiment and analyzed in the study.

Literature Review

Agroforestry

The concept of growing agronomic crops with trees is not a new idea. In Asia, pond cypress is grown with rice to provide habitat for spiders that prey on rice-eating leafhoppers (Shi and Gao 1986). Coffee is often raised under the shade of taller trees to help control weed growth in Latin America (Staver et al. 1993). Agroforestry history is rich in the temperate region of the North America as well. Before the settlement of North America by Europeans, Native Americans are believed to have employed agroforestry techniques to produce food, improve hunting grounds, and gather raw materials (Williams et al.1997, Kimmins 1997). Europeans introduced livestock to North America and often managed them in silvopastoral systems. The practice of harvesting syrup from sugar maple (*Acer saccharum* Marsh.) was taught to the Europeans by the Native Americans and utilized by both peoples (Williams et al. 1997). Later, during the Dust Bowl of the 1930s, 30,000 km of shelterbelts were established with the help of the U.S. government (Droze 1977). More recently, in southern Ontario, barley, corn, and soybeans were grown for up to four years with newly planted tree seedlings in widely spaced rows, giving farmers four years of income to offset the cost of planting trees (Gordan and Williams 1991). Also, in the temperate region, the practicality of growing row crops between high quality trees was tested and found to be economically feasible (Benjamin et al. 2000).

Weed Control During Tree Establishment

Control of herbaceous vegetation is essential when establishing trees. Initially, grasses and broadleaved weeds are more competitive than tree seedlings for essential light, water, and nutrients, decreasing tree growth and survival. The three most frequently used types of weed control are chemical, mechanical, and physical barriers. Many studies have shown that chemical weed control (herbicides) provide the most beneficial weed control in terms of tree growth (Alley et al. 1999, Cogliastro et al. 1990, Van Sambeek and Rietveld 1982). Herbicides, however, leave the soil surface prone to erosion and can lead to soil degradation (Pimentel et al. 1995). In many cases, hardwood tree species are susceptible to damage from herbicides as well. In some situations, like a riparian buffer strip, tree growth is not necessarily a top priority; therefore, herbicides might not be the best option for weed control.

The two most common types of mechanical weed control are mowing and tillage. Mowing, though, is considered to be a poor option, because it stimulates the roots of weeds, further enhancing competition for nutrients and moisture (von Althen 1991). It is also easy to damage or eliminate trees with a mower. Cultivation or tillage can be an effective method of controlling weeds (Cogliastro et al. 1990, Kennedy 1984), although damage to tree stems and roots is possible in this method from lackadaisical operation of machinery. Furthermore, the soil surface is left bare, creating an opportunity for soil erosion.

An alternative to herbicides and machinery is the use of physical barriers to suppress the weeds around the trees. Physical barriers can include organic mulches and inorganic materials, such as plastics. Arthur and Wang (1999) showed that sawdust mulch can be an effective way of controlling weeds and it increased soil organic matter and soil moisture in young Christmas tree plantations. Plastic mulch can also be an effective weed control method (Utkhede and Hogue 1998, Appleton et al. 1990). Nevertheless, physical barriers can be expensive, and N levels in the soil are reduced with certain mulches (Allison 1965).

The use of forage crops for weed control in tree plantings may be an alternative to these traditional methods.

Forage Crops and Trees

The ideal forage crop for weed control will keep out highly competitive vegetation, grow well, and not be competitive with the trees, so that the trees maintain a reasonable growth rate. While any forage crop will compete with trees, a preferable one would be less competitive than other crops and weeds. Forage crops can also provide additional benefits. Some forage crops, such as legumes, increase nitrogen levels in the soil, boosting soil fertility (Willumsen and Kristensen 2001, Zemenchik 2001, Seguin et al 2000). This can be beneficial to tree growth, because most forest soils are low in N (Schoeneberger et al.1989, Van Sambeek 1985).

A study conducted in Missouri found that red clover (*Trifolium pratense* L.) and ladino clover (*T. repens* L.) are ideal cover crops for hardwoods (Alley et al. 1999). Red clover provided enough cover to suppress weeds, yet interfered the least with seedling growth. Red clover, though, has little tolerance to shade. Its growth was reduced significantly with 50% shade in an experiment done by Watson et al. (1984). Ladino clover had higher coverage, though tree seedling growth was not as great as in the red clover plots.

Benchmark and Justus orchardgrass (*Dactylis glomerata* L.) and timothy (*Phileum pratense* L.) are recommended as forage crops for use during tree establishment and in plantations with wide spacing, because they are slightly shade tolerant (Lin et al. 1999). Forage crops, like smooth bromegrass (*Bromus inermis* Leyss.), hog peanut (*Amphicarpaea bracteata* L.), *Desmodium paniculatum* L., and *D. canscesns* L., are even more shade tolerant, so they could be used in mature forest settings or silvopastoral systems (Lin et al. 1999).

Vetches (*Vicia* spp.) are better suited to be grown with hardwoods than conifers, because their viney limbs tend to shade out the lower branches of the conifers (Alley et al. 1999). Van Sambeek and Rietveld (1982) reported that black walnut trees grown with hairy vetch (*Vicia villosa* Roth.) were almost as tall as trees grown in chemically weed-controlled plots.

Not all forage crops are ideal cover crops with trees; this can be especially true when there is high competition for water and nutrients. In cases were nutrients are limited and fertilizer applied, the fertilizer may be better utilized by the forage plant, further suppressing tree growth. Tall fescue (*Festuca arundinacea* Schreb.) produces a high forage yield but is deep rooted and competes heavily with trees (Roth and Mitchell 1982, Todhunter and Beineke 1979). Growth of black walnut seedlings was reduced by 75% when fescue was present (Todhunter and Beineke 1979). Besides its high growth rates, tall fescue is thought to have an allelopathic affect on black walnut that would account for the growth reduction in young walnut seedlings (Rink and Van Sambeek 1985). Alfalfa (*Medicago sativa* L.) is a cover crop that is widely used in Iowa for hay production but is considered too aggressive to be grown with trees. An additional disadvantage of alfalfa is that its growth is reduced in shaded conditions (Watson et al. 1984).

Information regarding warm season grasses has shown mixed results in their effectiveness as cover crops. In the southeastern United States, timber production was increased in loblolly pine sawtimber plantations when grown with warm season grasses, such as bahiagrass (*Paspalum notatum* Flugge.) and bermudagrass (*Cynodon dactylon* L.) (Clason

1999). In contrast, Weller et al (1995) found that peach tree growth was reduced when planted with bermudagrass and that competition for water and nutrients was excessive.

Trees can have a positive effect on cool season forage crops. Shade from walnut trees has been shown to increase orchardgrass (*Dactylis glomerata* L.) and reed canarygrass (*Phalaris arundinacea* L.) yields by as much as 33 percent and digestibility by 10 percent (Garrett and Kurtz 1983). Kephart and Buxton (1993) found that shade could increase forage quality in C3 and C4 grasses, because more stressful conditions will reduce photosynthate, which can increase forage quality.

Rodents, such as field mice, gophers, and voles, are a concern among tree growers trying to establish new plantings (Sullivan et al 2001). Rodents can consume the outer layer of tree tissue, reducing tree growth and, in some cases, causing mortality, particularly in winter months (Merwin et al. 1998). Smallwood (1996) found that pests were most common in cahaba white vetch (*Vicia sativa* L. x *V. cordata* Wulf.) and were not as copious in grasses and subclover mixes. Merwin et al. (1998) found vole densities highest in crown vetch (*Cornilla varia* L.). This information should be taken into consideration when deciding which forage crop to establish with trees.

Direct Seeding

Direct seeding is a form of artificial regeneration in which seeds are spread across the area being planted instead of planting seedlings. Seeding can be done through the air via helicopter or airplane, with on-ground machinery, such as a broadcast spreader, or directly by hand. Direct seeding was a prevalent method of regenerating forests in the 1950s, but interest has waned because many chemicals that were used to protect the seeds from predation were banned. Rodents can be a major problem in direct seeded areas, eating the seeds and reducing regeneration on the site (Wendel 1979).

Direct seeding, however, is used in areas that are remote or have unfavorable topography for machinery, or as an alternative to planting seedlings. Direct seeding is also a common method of establishing trees on mine spoils of reclaimed surface mines (Tolbert et al 1995, Thor and King 1964). Direct seeding is most common with coniferous species and has been proven to be successful in many areas (Winsa and Bergsten 1994, Van-Damme 1991, Hazel et al.1989). One of the reasons for greater success with conifers than hardwoods is the fact that coniferous seeds are able to be stored longer than hardwood seeds. Whereas hardwood seeds are usually stored for no more than one season, properly dried conifer seeds are still 95% viable after five years (Belcher 1986).

Planting tree seedlings is the most common way of establishing trees in Iowa, although some problems may arise. Seedlings with large taproots, such as oaks and walnuts, are easily damaged during lifting from the nursery and planting (Smith et al. 1997, Wendel 1979). In addition, shock can take place with transplanted trees, when they are removed from the nursery and planted in the field, leading to slower growth of the transplanted trees.

Direct seeding may be a technique to avoid these problems for some species. Although seedlings are more developmentally advanced than the seeds when planted, that does not guarantee they will grow faster. In a study conducted in Virginia, black walnut trees from seed were just as tall as walnut trees from seedlings after seven years (Dierauf and Garner 1984). This same scenario occurred with the walnut trees in the FATE study. After four years, the walnut trees from seed were, on average, as tall, or taller than trees from seedlings. These results are not restricted to black walnut. A six-year study conducted in

Pennsylvania found that northern red oak (*Q. rubra* L.) acorns did just as well as 1-0 seedlings, but not as well as the 2-0 seedlings (Zaczek et al. 1997).

Direct seeding has also been used to effectively establish stands all across North America. In the southeastern United States, sawtooth (*Q. acutissima* Carruth.), nuttall (*Q. nutallii* Palmer), water (*Q. nigra* L), willow (*Q. phellos* L.), and Shumard oaks (*Q. Shumardii* Michx.) have been successfully regenerated with direct seeding (Goelz and Carlson 1997, Wittwer 1991, Francis and Johnson 1985, Johnson 1981). Since 1985, the Louisiana Department of Natural Resources has direct seeded over 4,000 acres in the Quachita wildlife mangement area, and 5,000 acres have been sown in the lower Mississippi river valley by private and public landowners (Kennedy 1990). Black locust (*Rubinia psuedoacacia* L.) is readily established by direct seeding in the Appalachian Mountains (Tolbert et al 1995), and direct seeded silver birch (*Betula pendula* Roth.) and downy birch (*Betula pubescens* Ehrh.) have been established for timber production in Canada (Cameron 1996).

A possible benefit of direct seeding is the fact that many more seeds are sowed than seedlings planted on a given acre. This may increase the genetic variability of the newly planted forest, while only the most fit seedlings for that environment will survive. An additional advantage of direct seeding is that it can be cheaper than planting seedlings (Lopez-Barrarea and Gonzalez-Espinosa 2001). By eliminating nursery costs and reducing planting costs, Bullard et al. (1992) found direct seeding to be a viable economic alternative to planting seedlings for oak establishment.

CHAPTER 2. IMPROVING TREE ESTABLISHMENT WITH FORAGE CROPS

A paper to be submitted to The Northern Journal of Applied Forestry

Eric J. Holzmueller and Carl W. Mize

Abstract

Tree establishment in Iowa can be difficult without adequate weed control. Although herbicides are effective at controlling weeds, they may not be desirable in some situations. An alternative to herbicides is using forage crops as cover crops to control weeds. The objectives of this research were: (i) evaluate the influence of various weed control methods on the growth and survival of five tree species and (ii) determine the cost effectiveness of planting trees with different weed control treatments. Seven weed control treatments were used: (i) oats (*Avena sativa* L.) and red clover (*Trifolium pratense* L.), (ii) oats, red clover, and red fescue (*Festuca rubra* L.), (iii) oats, red clover, and orchardgrass (*Dactylis glomerata* L.), (iv) oats and hairy vetch (*Vicia villosa* Roth.), (v) herbicide, (vi) mowing, and (vii) control (no treatment). Five species of trees were planted in two groups; the first group (fast-growing trees) contained two poplar (*Populus* spp.) clones [Crandon (*P. alba* L. x *P. grandidentata* Michx.) and Eugenii (*P. deltoids* Bartr. x *P. nigra* L.)] and silver maple (*Acer saccharinum* L.). The second group (slow-growing trees) consisted of high-value hardwoods, red oak (*Quercus rubra* L.) and black walnut (*Juglans nigra* L.), both planted from seedlings and seeds. Height and survival were measured yearly for all tree species, and

forage crop coverage was estimated during the third and fourth growing seasons. The treatments did not appear to influence seedling survival ($P \geq 0.28$). Trees grown in herbicide plots were significantly taller (3.2 m) than those in the other treatments (2.5 m) ($P<0.02$). Forage treatments outperformed mowing and control treatments in three out of four experimental groups ($P \leq 0.05$). In addition, after four years black walnut seedlings from seed were taller (1.4 m) than planted seedlings (1.2 m) ($P \leq 0.02$), indicating direct seeding is a viable alternative to planting seedlings. An economic analysis was conducted by estimating the costs and returns with different weed control treatments for black walnut and Crandon. For black walnut, net present value increased by $438/ac when forage crops were used for weed control and harvested versus using herbicides for weed control. Under the same scenario, Crandon net present value decreased $861/ac.

Introduction

In the late 1800's, an estimated six and a half million acres of forest covered Iowa (Wider 1968). Currently there is an estimated two million acres of forest in the state (USDA 1997). Many of the nearly four million acres that were forested have been converted to farmland that is used for crop production or pasture. Most of these acres are susceptible to high erosion rates and degradation under current agricultural practices. In Iowa, over eight million acres of cropland are considered highly erodible (USDA 1997), and many of those acres are converted forest land. When perennial plant communities are replaced with annual crops, nutrients are more likely to leach through the soil and microbial activity in the soil is reduced in response to soil compaction and lower levels of soil C (Schultz et al. 2000).

Establishing trees on these highly erodible acres would take them out of agricultural production and decrease erosion and fertilizer and pesticide runoff.

In order to establish trees, weed control is essential. Two of the most common methods for controlling weed are herbicides and mowing. Many studies have shown that herbicides provide the most beneficial weed control in terms of tree growth (Alley et al. 1999, Cogliastro et al. 1990, Van Sambeek and Rietveld 1982). Herbicides, however, leave the soil surface prone to erosion and can lead to soil degradation (Pimentel et al. 1995). In some situations, like riparian buffer strips, tree growth is not necessarily a top priority, and in other situations landowners may be opposed to the use of herbicides. Therefore, herbicides might not always be the best option for weed control. Another commonly used weed control method is mowing. Mowing, though, is considered to be a poor option, because it stimulates the roots of weeds, further enhancing competition for nutrients and moisture (von Althen 1991). The use of forage crops for weed control in tree plantings is an alternative to these traditional methods.

The ideal forage crop for weed control will keep out highly competitive vegetation and grow well. Although any forage crop will compete with trees, a preferable one would be less competitive than other crops and weeds. Red clover (*Trifolium pratense* L.), ladino clover (*T. repens* L.), Benchmark and Justus orchardgrass (*Dactylis glomerata* L.) and timothy (*Phileum pratense* L.) have all been identified as potential cover crops for tree plantings in Missouri, because of their ability to suppress weeds without drastically reducing tree growth (Alley et al. 1999, Lin et al. 1999).

In 1998, a research project called the Forage and Tree Experiment (FATE) was established to determine the effectiveness of forage crops as weed control cover crops. The objectives of the project were twofold. First, four commonly used forage mixtures compared growth and survival of three tree species and two poplar clones against more traditional methods of weed control during tree establishment: herbicides, mowing, and no treatment. The second objective was to determine the cost effectiveness of planting trees with different weed control treatments.

Materials and Methods

Study Site

The field research was established at the Iowa State University Rhodes Research Farm, Rhodes, IA in the spring of 1998. Plantings were established on about two acres of land on a lowland site and two acres on an upland site. The predominant soil type for the upland site was Downs (fine-silty, mixed, mesic Mollic Hapludalf), and the bottomland soil type was Gara (fine-loamy, mixed, superactive, mesic Mollic Hapludalf). The bottomland site had been in pasture for many years, while the upland site was grassland, formally used for pasture. The bottomland site was grazed down, and then both sites were mold-board plowed before planting.

Project Design

Five species of trees were planted in two groups; the first group (fast-growing trees) contained two poplar (*Populus* spp.) clones [Crandon (*P. alba* L. x *P. grandidentata* Michx.) and Eugenii (*P. deltoids* Bartr. x *P. nigra* L.)] and silver maple (*Acer saccharinum* L.). The second group (slow-growing trees) consisted of high-value hardwoods, red oak (*Quercus rubra* L.), seedlings and seeds, and black walnut (*Juglans nigra* L.), seedlings and seeds. Of the seven weed control treatments, there were four small grain/forage crop combinations: (i) oats (*Avena sativa* L.) and red clover (*Trifolium pratense* L.), (ii) oats, red clover, and red fescue (*Festuca rubra* L.), (iii) oats, red clover and, orchardgrass (*Dactylis glomerata* L.), and (iv) oats and hairy vetch (*Vicia villosa* Roth.). Another treatment was complete weed control using herbicides. For the first year a preemergent mix of 1 lb of Goal™ and 2 lbs of Pendulum™ per acre was used. During the other years a preemergent mix of 2.5 lbs of Princep™ and 3 lbs of Pendulum™ per acre was applied. A 2% mix of Roundup™ was used for spot control during the growing season. The last two treatments were mowing, when the weeds were eight inches tall, and a control.

The upland and bottomland sites were divided into six blocks. On each site, three blocks were planted with fast-growing trees, and three blocks were planted with slow-growing trees. The overall design was four randomized complete block experiments with three blocks per experiment.

Each block for the fast-growing trees was laid out as a split plot design, and for slow-growing trees each block was a split-split plot design. The whole plots for fast-growing trees were 24 ft wide and 110 ft long. The fast-growing species were randomly assigned to subplots within each whole plot (Figure 1). The whole plots for high-valued trees were 24 ft wide by 100 ft long. The plots for high-value trees were divided into two subplots. The subplots were randomly selected to be planted with either seed or seedlings, and the subplots were divided into two sub-subplots, which were randomly assigned to be planted to red oak or black walnut (Figure 1).

The four small grain/forage crop treatments were all planted on one day in the spring of 1998. 'Ogle' oat, a high yielding cultivar that is compatible with forage establishment (Holland and Brummer 1999), was sown with a 12 ft wide commercial grain drill at 2 bu/ac.

Forages were overplanted with a Brillion drill. 'Flyer' red fescue was sown at 3 lbs/ac, 'Marathon' red clover at 8 lbs/ac, and 'Duke' orchardgrass at 5 lbs/ac, corrected for germination.

After planting the small grain/forage treatments, trees were planted in two rows, 12 ft apart, in all whole plots. For each fast-growing species, eight seedlings were planted per row. The slow-growing species had nine seedlings and 35 seeds planted per row. The spacing between seedlings in a row (3 ft and 2 ft) is less than half of the spacing used in a typical planting. These narrow spacings were used to have enough seedlings in a plot to reasonably estimate first year mortality. After measuring the trees at the end of the first growing season, every other tree from a seedling, depending upon mortality, was cut down and its stump treated with Roundup™ to prevent sprouting. None of the seedlings from seed were cut down, because normally all seedlings arising from direct seeding are left for at least seven years.

Shortly after establishing the study, electric fences were erected around each planting. The white tail deer population on the Rhodes farm is high, and red oak and silver maple are preferred browse species. The deer fence helped reduce browsing pressure on the bottomland site, but apparently did not do much good on the upland site, as most red oak and silver maple appear to have been browsed annually.

Measurements

Initial plans for the study called for harvesting the oats at grain maturity, and subsampling forages to determine yield. However, the spring and early summer of 1998 were very wet, restricting access to the sites for general maintenance. Following the rain came a period of hot and humid weather that caused a growth spurt in the weeds relative to the oats and forages in the treatment plots. When the ground dried enough to access the plots with equipment, weeds dominated both planting sites, particularly the bottomland one. Given the weed competition, forage production was very low. As a consequence, forage production was not measured. Instead, steps were taken to promote the growth of the forages by mowing the plots, because mowing is a practice used to help establish forages. Mowing was done three times during the growing season, which allowed the forages to increase to 80% or better coverage within the forage treatment plots. Mowing improved forage establishment but prevented forage production estimation. Mowing the forage plots twice a year was continued through the fourth growing season to help maintain the forage component for those plots. Yield estimates were made during the second year by using the rising plate method as described by Harmony et al. (1997), but because of weed problems, estimates were not reliable and are not reported.

The height of all surviving seedlings from planted seedlings and seed was measured each year during the fall.

Statistical Analysis

The data were separated into four experimental groups for analysis: upland slow-growing, upland fast-growing, bottomland slow-growing, and bottomland fast-growing. Analysis of variance was used to test for interactions between the species and treatments and main effects. Contrasts (Snedecor and Cochran 1980) were done to compare the control versus mowing, vegetative treatments versus control and mowing, vegetative treatments versus herbicides, and among the four vegetative treatments. All statistical analyses were done using SAS (SAS Institute 1989). Significance was determined at the 0.10 level.

Results

Survival

After four year, the number of seedlings alive from direct seeding of 210 seeds per treatment ranged from 47 to 75 seedlings per treatment for black walnut and 1 to 13 seedlings per treatment for red oak. The number of red oak seedlings from seed was so low that it was dropped from further analyses. Over all treatments the number of black walnut seedlings from seed was slightly smaller on the upland site, 443 seedlings, than on the bottomland site, 469 seedlings (Table 1). Thirty-one percent of the black walnut seed that produced a seedling in the first year survived through the fourth growing season, and there were no significant differences in survival rates among the treatments on either site ($P \geq 0.75$). Survival for the other species and clones was quite high (80-97%) on both sites, with no significant differences among treatments ($P \geq 0.28$).

Height Growth

Overall, height growth was generally good for Crandon, Eugenii, and black walnut and variable for silver maple and red oak seedlings (Table 2). After two growing seasons there were no significant differences in height among the seven weed control treatments ($P \geq 0.16$). At the end of four growing seasons, however, there was a significant difference among the treatments for the fast-growing species on both sites ($P \leq 0.02$) and the slow-growing species on both sites ($P \leq 0.06$).

At the end of the fourth growing season, trees on the bottomland site were taller than on the upland site, particularly Eugenii (6.1 m bottomland versus 3.5 m upland) and silver maple (2.6 m bottomland versus 1.0 m upland), although deer browse is probably partially responsible. The treatments varied in height growth depending on the species. Because there often are no differences between the mowing and control treatments, a contrast was used to compare their means (Table 3) and showed no significant difference in tree height for each experimental group ($P \geq 0.25$). Because the mowing and control treatments were not different, they were combined to create a stronger statistical comparison against the average tree height of the four forage treatments. Except for the bottomland, slow-growing trees, tree height increased when planted with forage crops compared to the mowing and control treatments ($P \leq 0.05$). In all four experimental groups the trees in the herbicide treatments were significantly taller than trees in the combined forage treatments ($P \leq 0.02$). Contrasts among the forage treatments showed no significant difference in tree height ($P \geq 0.14$) on three of the four experimental groups, the bottomland slow-growing group being the only group to show a difference ($P = 0.01$). This was because trees in the hairy vetch treatment were, on average, shorter than trees in the other forage treatments (Table 2).

To evaluate direct seeding, black walnut from planted seedlings and buried seed were compared over the four growing seasons for the upland and bottomland sites. Figure 2 illustrates how the height of planted seedlings and seedlings from seed has changed over time. Initially, the planted seedlings on both sites were stagnant, growing less than 0.1 m between the first and second year, while in two years the seedlings from seed grew nearly 0.5 m on the upland, and 0.6 m on the bottomland. The seedlings from seed on both sites surpassed the planted seedlings during the third growing season. After four growing seasons, the final height of the upland walnut from seed was 1.3 m verses 1.1 m for the planted seedlings. This was significantly different ($P = 0.02$), as was the difference for the bottomland site 1.5 m for the seedlings from seed to 1.3 m for the planted seedlings ($P = 0.006$). Contrasts done to estimate treatment effects (Table 3) showed no significant difference among the mowing and control treatments for both sites ($P \geq 0.34$), although seedlings from seed were taller than planted seedlings on both the upland and bottomland site for the vegetative treatments ($P \leq 0.06$). Comparisons among the herbicide treatments showed a significant difference between the seedlings from seed and planted seedlings on the bottomland site ($P=0.05$), but not for the upland site ($P=0.86$).

Forage Coverage

Forage coverage ranged from excellent (100%) to poor (1%) depending on the year, treatment, and site (Table 4). Forage crop coverage was usually greater on the upland site than the bottomland site. There was a difference ($P<0.001$) in the amount of forage coverage among the four treatments with the red clover and orchardgrass treatment having the highest coverage (>70%) on all plots after four years. Red fescue were the only forage crop to increase coverage in the fourth growing season in all experimental groups. Red clover showed a significant decrease ($P<0.001$) in all treatments during the fourth growing season, when grown alone and when grown in combination with the grasses. Hairy vetch produced the least amount of coverage, ranging from 1-17% on the two sites.

Economic Analysis

An economic analysis was conducted to better understand the potential impacts of some of the treatments. Net present values (NPV) and equivalent annual annuities (EAA) (Klemperer 1996) at a 7.5% alternative rate of return were calculated for Crandon and black walnut trees, established via seeds and seedlings, under five management regimes: (i) chemical weed control, (ii) oats and red clover without harvest, (iii) oats, red clover, and red fescue without harvest (iv) oats and red clover, and (v) oats, red clover, and red fescue. In management regimes (iv) and (v) the cover crops would be harvested and sold, while in management regimes (ii) and (iii) the cover crops would be mowed twice a year to maintain coverage. Weed control and the harvesting of forage crops would last for three years. Forage crop yield estimates were reduced by 40% in the second growing season and 60% in the third growing season for Crandon because of the species high growth rates and lower branching characteristics. Land costs, taxes, and management costs were not included, and it was assumed that the land would be in perpetual forest after initial establishment.

Tree spacing in management plans (i), (ii), and (iii) would be 6x10-ft for Crandon, 10x10-ft for black walnut seedlings, and 2900 seeds/ac distributed in rows 10-ft apart for black walnut from seed. In the management plans that call for harvesting of the forage crops (iv) and (v), the spacing would be wider, 6x25-ft for Crandon, 10x25-ft for black walnut seedlings, and 25-ft between rows with 1100 seeds/ac for black walnut from seed. This wider spacing would enable farm machinery to harvest the forage crop easily.

Costs and returns (Table 5) for the various operations were obtained from Iowa State University researchers, extension personnel, and forestry consultants in Iowa. The short-term analysis (Table 6) shows what NPV and EAA will be from site preparation, tree establishment, weed control costs, and returns from forage harvest, if applicable, after three years. The long-term analysis (Table 7) is based on costs and returns of a 60-year rotation for the black walnut and 10-year rotation for Crandon. By calculating the EAA for Crandon and black walnut, a comparison can be made that takes into account uneven rotational periods. The sites were assumed to be of average productivity, SI 65 for black walnut, similar to the FATE sites. Timber volume for the black walnut was estimated from the size of the trees at the end of the rotation using the Doyle log rule table (Paul Wray, Iowa State

University, April 10, 2002). Volume estimates for Crandon were determined by yields obtained from other studies conducted by ISU forestry researchers. The final products for black walnut would be veneer and sawlogs, while Crandon would be harvested for biomass.

After three years, the short-term analysis (Table 6) showed a range of NPV from –$573 to $106/ac and the EAA ranged from $–573 to $41ac/yr. All returns were negative in the herbicide treatments and vegetative treatments, in which crops were not harvested. Positive returns were obtained for black walnut seedlings from seed and planted seedlings in treatments in which forage crops were harvested, with the greatest return coming from black walnuts from seed (EAA $41ac/yr).

In the long-term analysis (Table 7) NPVs ranged from $1610/ac (Crandon, herbicide treatment) to $-370/ac (black walnut planted seedlings, herbicide treatment). These two groups also had the highest $194/ac/yr and lowest $-28/ac/yr EAAs. Crandon had positive returns in every treatment, and the black walnut, seeds and seedlings, had positive returns in treatments that harvested forage crops.

Discussion

The red oak from seed did not survive as well as the other species. It had decent germination (20%), compared to 35% for black walnut, but very poor survival (2%) after four years, versus 35% for black walnut. This indicates that below ground predation of the seedlings from seed was not a problem, as observed in other studies (Johnson 1981, Wendell 1979). However, deer are numerous in the study area, and even though electric fencing was set up, it appears that they browsed on the red oaks (seeds and seedlings) and silver maple. For the red oak from seed that did survive, height did not vary among the treatments

(P=0.94). In addition, the seedlings from seed that did survive were not as tall as the planted 1-0 seedlings, 1.0 m for the planted red oak seedlings on both sites versus 0.4 m (upland) and 0.6 m (bottomland) for the red oak from seed, although no statistical comparisons were made due to the lack of data. Similar results were reported by Wittwer (1991) and Wendel (1979). Pressure from browsing, evidence of winterkill, and a slow growth rate compared to coexisting vegetation all appear to have contributed to the demise of the red oak from seed.

In addition to its higher survival rates compared to red oak from seed, black walnuts from seed were significantly taller than the planted walnut seedlings on the upland (P= 0.02) and bottomland (P=0.006) sites after four years. Similarly, Dierauf and Garner (1984) showed that after seven years direct seeded seedlings were nearly as tall as planted seedlings and growing at similar rates. Reasons for this somewhat surprising phenomenon could be that the root system of the planted seedlings is damaged at the nursery during the lifting operation (Smith et al. 1997). The seedlings may also suffer from transplant shock when removed from the nursery and planted into the field with unbalanced root to shoot ratios.

In the first two growing seasons, there was no significant difference in average height among the treatments for all species on both sites (P≥0.16). As was expected though, after four years, usage of herbicides resulted in the fastest tree growth for all tree groups (P≤0.02), which is consistent with other findings (Alley et al. 1999,Cogliastro et al. 1990, Van Sambeek and Rietveld 1982). In the herbicide plots the trees are essentially growing free from competition, and while the cover crops do reduce competition from weeds for the trees, they still compete for nutrients, light, and water. Nevertheless, the forage treatments resulted in greater growth than either mowing or the control (P≤0.05) for all but the bottomland slow-growing trees (P= 0.98). However, the bottomland slow-growing tree group also had the sparsest forage coverage in each vegetative treatment after four years (Table 5). Weeds were a problem on the bottomland site, especially during the first year, when heavy rains made the site impassible and prevented equipment from being brought in to harvest the forage crop.

There was little difference in the average tree height among the forage treatments. Contrasts made among the forage treatments showed no significant difference in height ($P \geq 0.14$) on three of the four experimental groups. The bottomland slow-growing group was the only one to show a difference among the forage treatments ($P = 0.01$), which is due to the poor tree growth in the hairy vetch treatment. Coverage, however, was not equal among forage treatments ($P < 0.001$). The orchardgrass and red clover treatment had the highest coverage after four years, ranging from 88% to 70% on all sites, orchardgrass dominating the mixture with red clover after four years with an average coverage of 73% versus 5%, respectively. Orchardgrass, a perennial, is a highly competitive grass that is more shade tolerant than red clover.

At the end of the fourth growing season, hairy vetch had the lowest coverage on both the upland and bottomland sites, 2% and 5%, respectively. Hairy vetch, an annual, did not reestablish after the initial growing season, because of high competition from weeds. After the first year, coverage in the hairy vetch plots consisted of mostly weeds. In the red clover only treatment, coverage of the crop decreased on average 48% between the third and fourth years, and a 36% decrease of red clover occurred in the red clover and red fescue treatment.

In the short-term economic analysis (Table 6) the oats, red clover and red fescue treatments had the highest NPVs, ranging from -$56/ac (Crandon) to $106/ac (black walnut from seed). NPVs in forage crop management regimes that were not harvested were considerably more expensive, from -$526/ac (Crandon) to –$307/ac (black walnut from seed), because they produced no income in the early years of tree establishment. Herbicides were the most expensive treatment overall, NPVs ranged from -$573 (Crandon) to -$358 (black walnut from seed). Black walnuts from seed either made more money or were less expensive than black walnuts from seedlings in every management regime, because of lower establishment costs. Crandon was the most expensive planting in the short-term analysis in every management regime compared to the black walnuts due to higher establishment costs and reduced forage yields in the harvestable management regimes.

The long-term analyses (Table 7) produced different results. Crandon had the highest NPV $1610/ac and EAA $235/ac/yr in the herbicide treatment, and had positive returns in every other management option. It is important to remember, however, that the market for Crandon biomass can be somewhat limiting in many areas and this should be taken into consideration before establishing a biomass plantation. Black walnut seedlings from seed and planted seedlings only had positive returns in the management regimes where forages were harvested; all other options were negative. These results are similar to Kincaid et al (1982) that showed black walnut grown in timber only options produced negative returns.

This study indicates that in the case of black walnut, more intensive management of the land, for example growing and harvesting forage crops with trees, will produce better returns. Garrett et al (1991) found similar results. Crandon, however, when grown in a biomass plantation, will produce better returns when tree rows do not have to be wider for harvesting operations.

These returns could also be affected when government programs, like the Conservation Reserve Program, and tax credits are taken into consideration. Some of these programs could help pay for tree establishment costs but might only allow harvesting of crops, trees or forage, under special circumstances. Another item that could increase returns, although it was not presented as a management option, would be to use animals to harvest the forage crops. Fencing, however, would be necessary to protect the smaller trees. If grazed properly, the expense of harvesting the forage crop would be eliminated, increasing returns from the land.

Finally, black walnut from seed not only had higher growth rates than black walnut seedlings, they also had higher returns than planting seedlings, indicating that direct seeding is a economically and ecologically feasible way of establishing black walnut. In many direct seeding plantings though, the seeds are not planted in rows, but rather broadcasted over the entire site to be planted. Finding an appropriate herbicide for weed control after the trees have been planted in a broadcast planting has been difficult when hardwood species are used. In some cases, high levels of green ash (*Fraxinus pennsylvanica* Marsh.) seed are spread with other species as an inexpensive way to maintain tree coverage and reduce competition from herbaceous vegetation. This method, however, can produce stands with higher levels of green ash than desired because the green ash ends up out competing more desirable species, such as, oak and black walnut. An alternative would be to use a cover crop instead of green ash to allow for the development of more desirable species, like oaks and black walnut, while reducing herbaceous vegetation competition.

Conclusions and Management Implications

Although the herbicide treatment resulted in significantly greater growth, the percentage increase in growth is not large compared to the growth on the vegetative treatments. Thus, the apparent "loss" in productivity due to using forage crops as a way to help establish trees would be a minor concern in situations in which tree growth is not a primary consideration. Herbicides, however, should be considered when trying to get trees to grow above the deer browse line, although an alternative plan may be needed, such as fencing.

Direct seeding is a viable technique for establishing black walnut seedlings. The trees were significantly taller, and the cost of establishment was cheaper. The same cannot be said for red oak, which had trouble becoming established after germination.

Our experiment showed once again that mowing does not increase tree growth and is not a viable option for weed control, because of underground competition for water and nutrients. Mowing and doing nothing result in adequate survival, although tree growth will be significantly lower when water and nutrients are limiting factors.

The red clover did not persist longer than three years. It showed a decrease in coverage during the fourth year and this trend is expected to continue. Depending on initial tree row spacing, further harvest of forage may not be possible, particularly for a species, such as Crandon, which has low branches that cover much of the plot after four years. If a more shade tolerant forage species were planted, for instance orchardgrass, harvesting of the crop would be possible after three years, given wide tree spacing, although this would reduce tree biomass yields. Orchardgrass and red clover would be a good combination, if forage production were the top priority, while still achieving adequate tree growth and survival.

The red clover and red fescue combination seemed to be the ideal cover mixture, if tree growth is top priority, while still producing an adequate forage crop. It was less competitive than the orchardgrass and red clover mixture, yet had better coverage than the red clover only and hairy vetch treatments.

The economic analysis showed that black walnut both from seed and planted seedlings will produce the highest returns when forage crops are harvested in the initial growing seasons, and that when forages are not harvested, they still produce better returns than herbicide weed control. It also showed that returns were higher for black walnut established from seed versus black walnut established from planted seedlings. For Crandon returns were highest over one rotation, when herbicides were used. Although, when planted with forage crops on a narrow spacing, which will prohibit forage harvest, comparable NPVs will be produced.

As no usable information on forage production was obtained from this study, we cannot conclude anything directly about the influence of trees on forage production. But given the small loss in tree growth due to the usage of small grain/forage crops, it is quite reasonable to conclude that given a reasonable level of production from the grain and forage crops, using such crops to help establish trees could be a viable technique.

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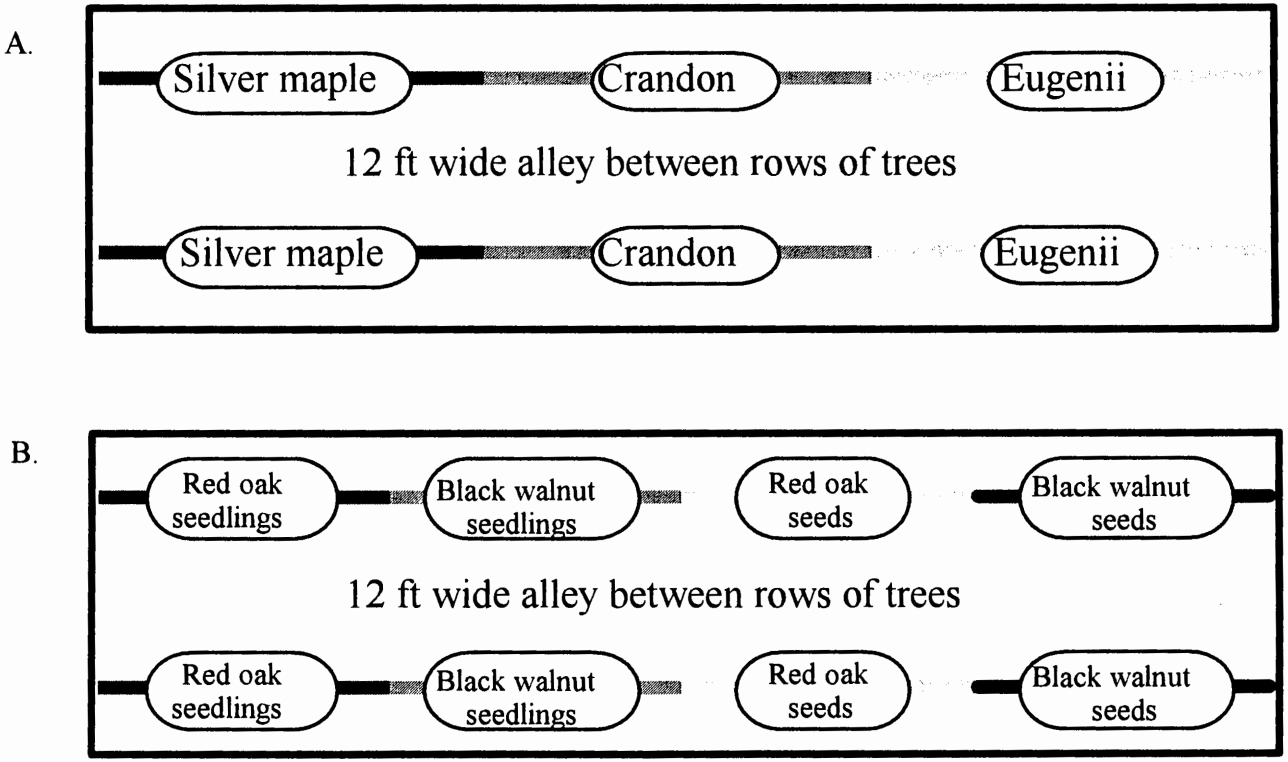

Figure 1. Examples of whole plots for the fast-growing trees (A) and the slow-growing trees (B).

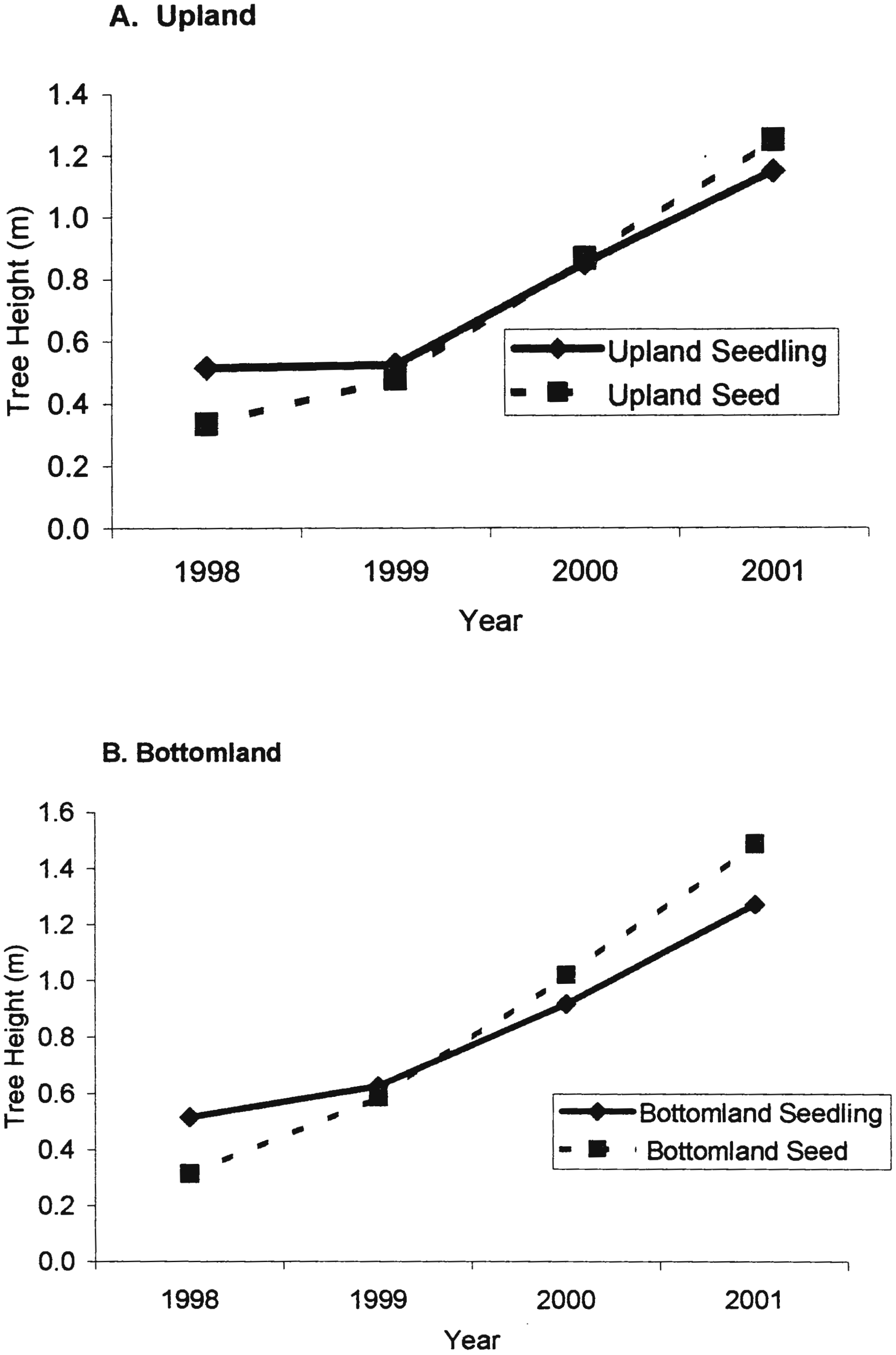

Figure 2. Height of black walnut from seed and planted seedlings measured at the end of the growing season, in October of each year, for (A) upland and (B) bottomland sites.

Table 1. Number of seedlings from seed for black walnut and red oak counted in each treatment during the first and fourth growing seasons on the upland and bottomland sites.

Treatment	Black Walnut				Red Oak				Seeds Planted
	Upland		Bottomland		Upland		Bottomland		
	First*	Fourth	First	Fourth	First	Fourth	First	Fourth	
Oats & Red Clover	65	65	70	57	32	1	62	7	210
Oats, Red Clover, & Red Fescue	68	64	78	75	30	1	29	1	210
Oats, Red Clover & Orchardgrass	74	60	61	67	9	1	54	3	210
Oats & Hairy Vetch	87	62	44	47	34	6	53	7	210
Herbicides	70	55	76	78	11	2	47	13	210
Control	94	70	81	74	40	3	66	3	210
Mowing	90	67	83	71	61	9	55	10	210
Total	548	443	493	469	217	23	366	44	1470

*First=First Growing Season, Fourth=Fourth Growing Season

Table 2. Average height of the tree species and clones in each weed control treatment for the bottomland and upland sites at the end of four growing seasons.

Treatment	Fast Growing Species						Slow Growing Species					
							Black Walnut				Red Oak	
	Crandon		Eugenii		Silver Maple		Seed		Seedling		Seedling	
	B*	U	B	U	B	U	B	U	B	U	B	U
	(m)		(m)		(m)		(m)		(m)		(m)	
Oats & Red Clover	5.6	5.3	6.6	3.4	2.5	0.9	1.4	1.4	1.3	1.2	0.9	0.7
Oats, Red Clover, & Red Fescue	5.9	6.1	6.1	3.6	2.8	0.9	1.8	1.4	1.2	1.2	1.0	0.8
Oats, Red Clover & Orchardgrass	5.7	4.7	6.0	3.6	2.4	0.9	1.4	1.1	1.3	1.1	1.1	0.8
Oats & Hairy Vetch	5.4	5.3	5.9	3.5	2.1	0.8	1.0	1.3	1.0	1.0	0.9	0.8
Herbicides	6.7	5.4	7.0	4.1	3.7	1.4	2.1	1.5	1.7	1.5	1.4	0.9
Control	5.1	3.9	5.3	3.1	2.5	1.4	1.5	1.0	1.3	1.1	0.9	0.8
Mowing	5.7	4.7	5.9	3.5	2.2	0.6	1.2	1.0	1.1	0.9	1.0	0.8
Average	5.7	5.1	6.1	3.5	2.6	1.0	1.5	1.3	1.3	1.1	1.0	0.8

* B=Bottomland, U=Upland

Table 3. Differences in average total height (m) based on contrasts between various treatment groups for fast-growing and slow-growing species on upland and bottomland sites. Values in parentheses are P values for null hypothesis of no difference between groups of treatments.

Contrast	Upland Fast-growing (m)	Bottomland Fast-growing (m)	Upland Slow-growing (m)	Bottomland Slow-growing (m)
Mowing vs Control	0.23 (0.25)	-0.30 (0.26)	0.10 (0.18)	0.11 (0.25)
Herbicide vs Vegetative	0.38 (0.02)	1.04 (<0.01)	0.24 (<0.01)	0.53 (<0.01)
Vegetative vs M&C*	0.41 (<0.01)	0.32 (0.05)	0.12 (<0.01)	0.0 (0.98)
Among Vegetative	(P=0.28)	(P=0.43)	(P=0.35)	(P=0.01)

*M&C- Mowing and Control

Table 4. Estimated coverage of forages in the forage treatments for the fast and slow-growing species on upland and bottomland sites during the third and fourth growing seasons.

	Fast-growing Species				Slow-growing Species			
	U[1]		B		U		B	
Treatment	**3**[2]	**4**	**3**	**4**	**3**	**4**	**3**	**4**
	(%)		(%)		(%)		(%)	
Red Clover	70	27	43	17	73	25	53	8
Red Clover &	80	33	27	7	67	17	30	3
Red Fescue	5	27	30	40	7	18	20	30
Red Clover &	20	10	13	3	20	5	10	2
Orchardgrass	80	63	53	67	77	83	80	77
Hairy Vetch	17	10	3	2	10	5	1	7

[1]U=Upland, B=Bottomland
[2]3=Third Growing Season, 4=Fourth Growing Season

Table 5. Costs and returns of practices in various management regimes used to determine NPV and EAA for Crandon and Black Walnut, seedlings from seed and planted seedlings.

Transaction	Dollars/Units
Site Preparation	20/ac
Seedlings-Crandon	0.35/tree
Black walnut	0.40/tree
Seeds –Black walnut	2/lb
Planting Seedlings	0.23/tree
Sowing Seeds	60/acre
Herbicides	47/acre
Crop Seeds-Oats	5/bu
Red Clover	1.35/lb
Red Fescue	1.15/lb
Forage Establishment	75/acre
Forage Harvest Cost	42.5/ton
Forage Maintenance	33/year
Thinning Direct Seeding	30/ac
Timber Stand Improvement	50/ac
Forage Biomass	75/ton
Oats	1/bu
Crandon Biomass	60/ton
Black Walnut	1.5/ bd ft

Table 6. Short-term economic analysis of net present value (NPV) and equivalent annual annuity (EAA) at a 7.5% alternative rate of return for Crandon and black walnut, both planted seedlings and from seeds, under various management regimes, after three years of establishment.

	Crandon		Black Walnut Seedlings		Black Walnut from Seed	
Management	NPV ($/ac)	EAA ($/ac/yr)	NPV ($/ac)	EAA ($/ac/yr)	NPV ($/ac)	EAA ($/ac/yr)
Herbicides	1610	235	-370	-28	-266	-20
Oats, Red Clover & Red Fescue	1439	210	-364	-28	-260	-19
Oats & Red Clover	1443	210	-360	-27	-256	-19
Oats, Red Clover, & Red Fescue (Harvested)	817	119	112	8	158	12
Oats & Red Clover (Harvested)	761	111	82	6	128	10

Table 7. Long-term economic analysis of net present value (NPV) and equivalent annual annuity (EAA) at a 7.5% alternative rate of return for Crandon and black walnut, both planted seedlings and from seeds, under various management regimes, after one rotation.

	Crandon		Black Walnut Seedlings		Black Walnut from Seed	
Management	NPV ($/ac)	EAA ($/ac/yr)	NPV ($/ac)	EAA ($/ac/yr)	NPV ($/ac)	EAA ($/ac/yr)
Herbicides	-573	-220	-485	-185	-358	-138
Oats, Red Clover & Red Fescue	-526	-202	-433	-166	-311	-120
Oats & Red Clover	-522	-201	-429	-165	-307	-118
Oats, Red Clover, & Red Fescue (Harvested)	-56	-22	42	16	106	41
Oats & Red Clover (Harvested)	-112	-43	13	5	77	29

CHAPTER 3. GENERAL CONCLUSIONS

General Conclusion

Under current agricultural practices, Iowa's soil is subject to high rates of erosion, and its streams are exposed to high levels of nutrient runoff from cropfields. Restoring some of these acres to forest would help reduce environmental degradation. Tree establishment in Iowa, however, can be expensive and difficult without adequate weed control. This study looked at using forage crops as an alternative to more traditional weed control methods: herbicides and mowing.

Although herbicides treatment did result in higher growth than the forage treatments, the growth was not enough to consider forage crops to be a lesser alternative. Herbicides were more expensive to apply than establishing and maintaining cover crops, and survival rates were essentially the same for both the herbicide and vegetative treatments. In addition, forage crops cover the soil surface year around, while herbicides leave the soil surface bare and prone to erosion.

In a situation in which a farmer would like to maintain an income from his/her land, using forage crops for weed control would be a good idea. Depending on the forage species planted, the farmer could get up to three years or more of income. For instance, we found that red clover persisted about three years, while orchardgrass still had good coverage after the fourth growing season. Tree species and spacing also effect how long a farmer could harvest a crop. For example, the Crandon clone of hybrid poplar had lower branches that essentially reduced the crop alleys too much after three years to make forage harvests feasible. On the other hand, planting a slower growing species, like black walnut or red oak, would allow one to extend harvesting for more than three years.

Another method of tree establishment that was analyzed in the FATE study was the use of direct seeding. The black walnuts from seed had excellent survival, cheaper establishment costs, and by the end of four years were growing faster and were taller than the planted seedlings. Although the red oak from seed did not fare nearly as well as the black walnut, this method should not be ruled out entirely for red oak. Direct seeding with oaks has been successful in other areas of the country and perhaps a change in methodology would have benefited the red oak in the FATE study. For example, sowing the seeds in fall instead of spring. It certainly seems that in some cases direct seeding is a viable alternative to planting seedlings.

The economic analysis showed that black walnut both from seed and planted seedlings will produce the highest returns when forage crops are harvested in the initial growing seasons, and that when forages are not harvested, they still produce better returns than herbicide weed control. It also showed that returns were higher for black walnut established from seed versus black walnut established from planted seedlings. For Crandon returns were highest, over one rotation, when herbicides were used. Although when planted with forage crops on a narrow spacing, which will prohibit forage harvest, comparable NPVs will be produced.

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APPENDIX

Table A1. Average height of the upland trees in the FATE study at the end of the first growing season.

Treatment*	Crandon (m)	Eugenii (m)	Silver Maple (m)	Red Oak from seed (m)	Red Oak Seedling (m)	Black Walnut Seedling (m)	Black Walnut from seed (m)
1	1.0	0.9	0.6	0.1	0.5	0.5	0.3
2	1.2	0.8	0.6	0.1	0.5	0.5	0.4
3	1.0	0.9	0.7	0.1	0.5	0.5	0.4
4	1.0	0.9	0.6	0.1	0.5	0.5	0.4
5	0.9	0.8	0.6	0.1	0.5	0.6	0.3
6	1.0	0.8	0.7	0.1	0.5	0.5	0.3
7	0.9	0.9	0.5	0.1	0.4	0.5	0.3
Average	1.0	0.9	0.6	0.1	0.5	0.5	0.3

*1=oats and red clover, 2=oats, red fescue, and red clover, 3=oats, orchardgrass, and red clover, 4=oats and hairy vetch, 5=roundup and preemergents, 6=control, 7=mowing

Table A2. Average height of the upland trees in the FATE study at the end of the second growing season.

Treatment*	Crandon (m)	Eugenii (m)	Silver Maple (m)	Red Oak from seed (m)	Red Oak Seedling (m)	Black Walnut Seedling (m)	Black Walnut from seed (m)
1	2.2	1.4	0.6	0.1	0.5	0.6	0.5
2	2.2	1.6	0.5	0.1	0.5	0.5	0.5
3	2.0	1.6	0.6	0.1	0.5	0.6	0.5
4	2.0	1.4	0.6	0.1	0.5	0.4	0.5
5	2.1	1.4	0.5	0.2	0.4	0.6	0.4
6	1.9	1.5	0.7	0.1	0.5	0.6	0.5
7	1.6	1.6	0.5	0.1	0.4	0.5	0.5
Average	2.0	1.5	0.5	0.1	0.5	0.5	0.5

*1=oats and red clover, 2=oats, red fescue, and red clover, 3=oats, orchardgrass, and red clover, 4= oats and hairy vetch, 5= roundup and preemergents, 6=control, 7=mowing

Table A3. Average height of the upland trees in the FATE study at the end of the third growing season.

Treatment*	Crandon	Eugenii	Silver Maple	Red Oak from seed	Red Oak Seedling	Black Walnut Seedling	Black Walnut from seed
	(m)	(m)	(m)	(m)	(m)	(m)	(m)
1	3.3	2.3	1.0	0.1	0.7	1.0	1.0
2	3.5	2.5	1.0	0.1	0.8	0.9	1.0
3	3.0	2.6	0.9	0.4	0.8	0.9	0.9
4	3.0	2.4	0.9	0.2	0.8	0.7	0.8
5	3.4	2.7	1.1	0.8	0.7	0.9	0.9
6	2.6	2.4	1.0	0.2	0.7	0.9	0.8
7	2.7	2.5	0.7	0.2	0.6	0.6	0.7
Average	3.1	2.5	1.0	0.3	0.7	0.8	0.9

*1=oats and red clover, 2=oats, red fescue, and red clover, 3=oats, orchardgrass, and red clover, 4=oats and hairy vetch, 5=roundup and preemergents, 6=control, 7=mowing

Table A4. Average height of the upland trees in the FATE study at the end of the fourth growing season.

Treatment*	Crandon	Eugenii	Silver Maple	Red Oak from seed	Red Oak Seedling	Black Walnut Seedling	Black Walnut from seed
	(m)	(m)	(m)	(m)	(m)	(m)	(m)
1	5.3	3.4	0.9	0.4	0.7	1.2	1.4
2	6.1	3.6	0.9	---	0.8	1.2	1.4
3	4.7	3.6	0.9	---	0.8	1.1	1.1
4	5.3	3.5	0.8	0.2	0.8	1.0	1.3
5	5.4	4.1	1.4	0.4	0.9	1.5	1.5
6	3.9	3.1	1.4	0.4	0.8	1.1	1.0
7	4.7	3.5	0.6	0.4	0.8	0.9	1.0
Average	5.1	3.5	1.0	0.4	0.8	1.1	1.2

*1=oats and red clover, 2=oats, red fescue, and red clover, 3=oats, orchardgrass, and red clover, 4=oats and hairy vetch, 5=roundup and preemergents, 6=control, 7=mowing

Table A5. Average height of the bottomland trees in the FATE study at the end of the first growing season.

Treatment*	Crandon	Eugenii	Silver Maple	Red Oak from seed	Red Oak Seedling	Black Walnut Seedling	Black Walnut from seed
	(m)	(m)	(m)	(m)	(m)	(m)	(m)
1	1.1	1.6	0.7	0.1	0.5	0.5	0.3
2	1.3	1.8	0.9	0.1	0.5	0.5	0.4
3	1.3	1.6	0.7	0.1	0.5	0.5	0.4
4	1.3	1.5	0.7	0.1	0.5	0.5	0.2
5	1.3	1.9	1.0	0.1	0.5	0.5	0.3
6	1.0	1.4	0.8	0.1	0.5	0.6	0.4
7	1.2	1.7	0.9	0.1	0.6	0.5	0.3
Average	1.2	1.6	0.8	0.1	0.5	0.5	0.3

*1=oats and red clover, 2=oats, red fescue, and red clover, 3=oats, orchardgrass, and red clover, 4=oats and hairy vetch, 5=roundup and preemergents, 6=control, 7=mowing

Table A6. Average height of the bottomland trees in the FATE study at the end of the second growing season.

Treatment*	Crandon	Eugenii	Silver Maple	Red Oak from seed	Red Oak Seedling	Black Walnut Seedling	Black Walnut from seed
	(m)	(m)	(m)	(m)	(m)	(m)	(m)
1	2.4	3.1	0.8	0.1	0.6	0.6	0.4
2	2.4	3.4	1.1	0.1	0.6	0.6	0.7
3	2.6	2.9	0.9	0.1	0.6	0.6	0.6
4	2.6	3.0	1.0	0.1	0.5	0.6	0.5
5	2.7	3.6	1.5	0.1	0.5	0.7	0.7
6	2.4	2.8	1.4	0.1	0.6	0.7	0.7
7	2.4	3.1	1.1	0.1	0.6	0.6	0.5
Average	2.5	3.1	1.1	0.1	0.6	0.6	0.6

*1=oats and red clover, 2=oats, red fescue, and red clover, 3=oats, orchardgrass, and red clover, 4=oats and hairy vetch, 5=roundup and preemergents, 6=control, 7=mowing

Table A7. Average height of the bottomland trees in the FATE study at the end of the third growing season.

Treatment*	Crandon	Eugenii	Silver Maple	Red Oak from seed	Red Oak Seedling	Black Walnut Seedling	Black Walnut from seed
	(m)	(m)	(m)	(m)	(m)	(m)	(m)
1	3.3	4.7	1.7	0.1	0.8	0.9	1.0
2	3.2	4.5	1.8	0.1	0.9	0.9	1.2
3	3.4	4.2	1.6	0.1	0.9	0.9	1.0
4	3.6	4.3	1.5	0.4	0.8	0.8	0.9
5	4.4	5.4	2.5	0.7	0.9	1.1	1.3
6	3.2	4.0	1.7	0.0	1.0	1.0	1.0
7	3.4	4.3	1.6	0.3	0.8	0.8	0.8
Average	3.5	4.5	1.8	0.2	0.9	0.9	1.0

*1=oats and red clover, 2=oats, red fescue, and red clover, 3=oats, orchardgrass, and red clover, 4=oats and hairy vetch, 5=roundup and preemergents, 6=control, 7=mowing

Table A8. Average height of the bottomland trees in the FATE study at the end of the fourth growing season.

Treatment*	Crandon	Eugenii	Silver Maple	Red Oak from seed	Red Oak Seedling	Black Walnut Seedling	Black Walnut from seed
	(m)	(m)	(m)	(m)	(m)	(m)	(m)
1	5.6	6.6	2.5	0.8	0.9	1.3	1.4
2	5.9	6.1	2.8	0.4	1.0	1.2	1.8
3	5.7	6.0	2.4	---	1.1	1.3	1.4
4	5.4	5.9	2.1	0.7	0.9	1.0	1.0
5	6.7	7.0	3.7	0.7	1.4	1.7	2.1
6	5.1	5.3	2.5	---	0.9	1.3	1.5
7	5.7	5.9	2.2	0.4	1.0	1.1	1.2
Average	5.7	6.1	2.6	0.6	1.0	1.3	1.5

*1=oats and red clover, 2=oats, red fescue, and red clover, 3=oats, orchardgrass, and red clover, 4=oats and hairy vetch, 5=roundup and preemergents, 6=control, 7=mowing

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